University of Saskatch
Department of Electrical E

EE372 Electronic Materials and Devices
Midterm Examination
Professor Robert E. Johanson

**PART A**
**(closed book)**

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Welcome to the EE372 Midterm. The examination has two parts. Part A consists of questions that test knowledge of basic concepts, and part B requires more involved calculations. Part A is closed book and closed notes. When you finish part A, hand it in (raise your hand) and then proceed to part B. Part B is open book; you may refer to your textbook (Kasap, any edition) but not to any other material such as notes or other books. You may also use a calculator for both parts. The examination lasts **2** hours.

Each problem is weighted equally. Show your work if the question involves more than a simple answer; credit will be given only if the steps leading to the answer are **clearly** shown. Partial credit will be given for partially correct answers but only if correct intermediate steps are shown. Write your answers on these pages.

**For part A, answer 4 of the 5 questions. Do not answer more than 4 questions.**

1. 10
2. 10
3. —
4. 9
5. 8

total 37/40

1. Photoelectric Effect

a) Circle any of the following that can be determined directly by data from a photoelectric experiment.

The ratio of charge to mass for the electron

The metal's work function

The uncertainty in the position of the electron ✓

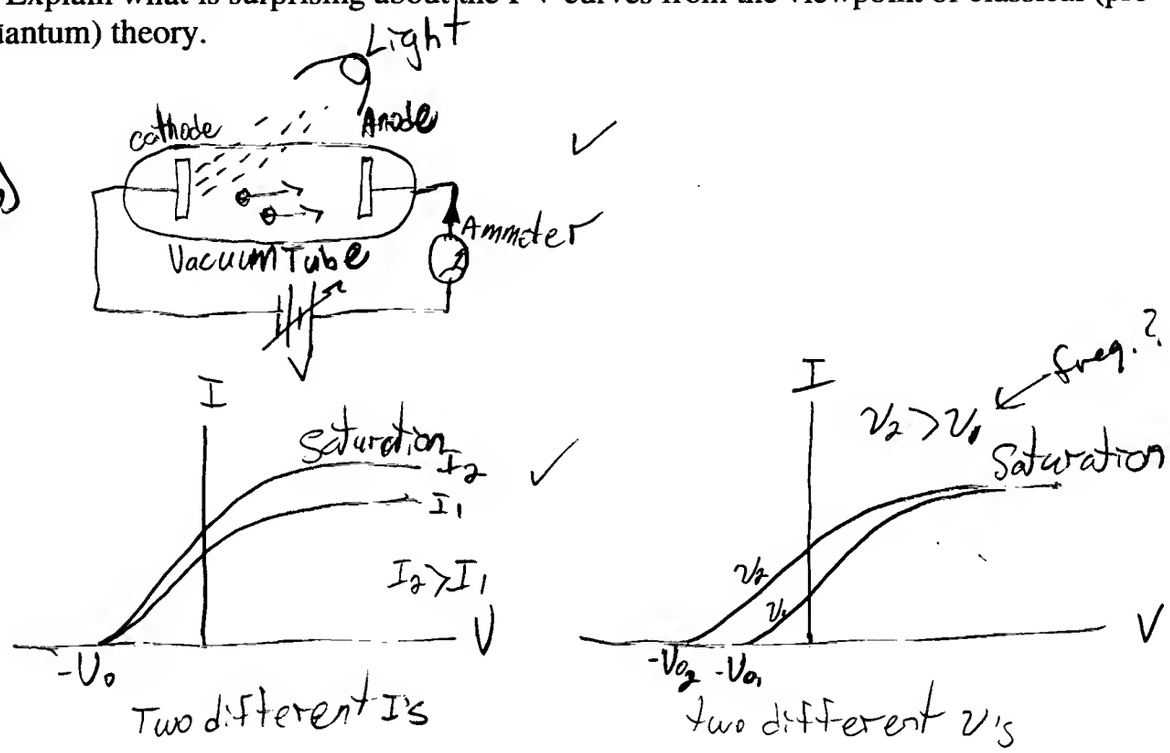
The photon's energy

The value of Planck's constant

The electron's DeBroglie wavelength

b) Sketch the apparatus and draw typical I-V curves for two different wavelengths of light and two different intensities. Indicate which is the longer wavelength and which is the greater intensity.

c) Explain what is surprising about the I-V curves from the viewpoint of classical (pre-quantum) theory.



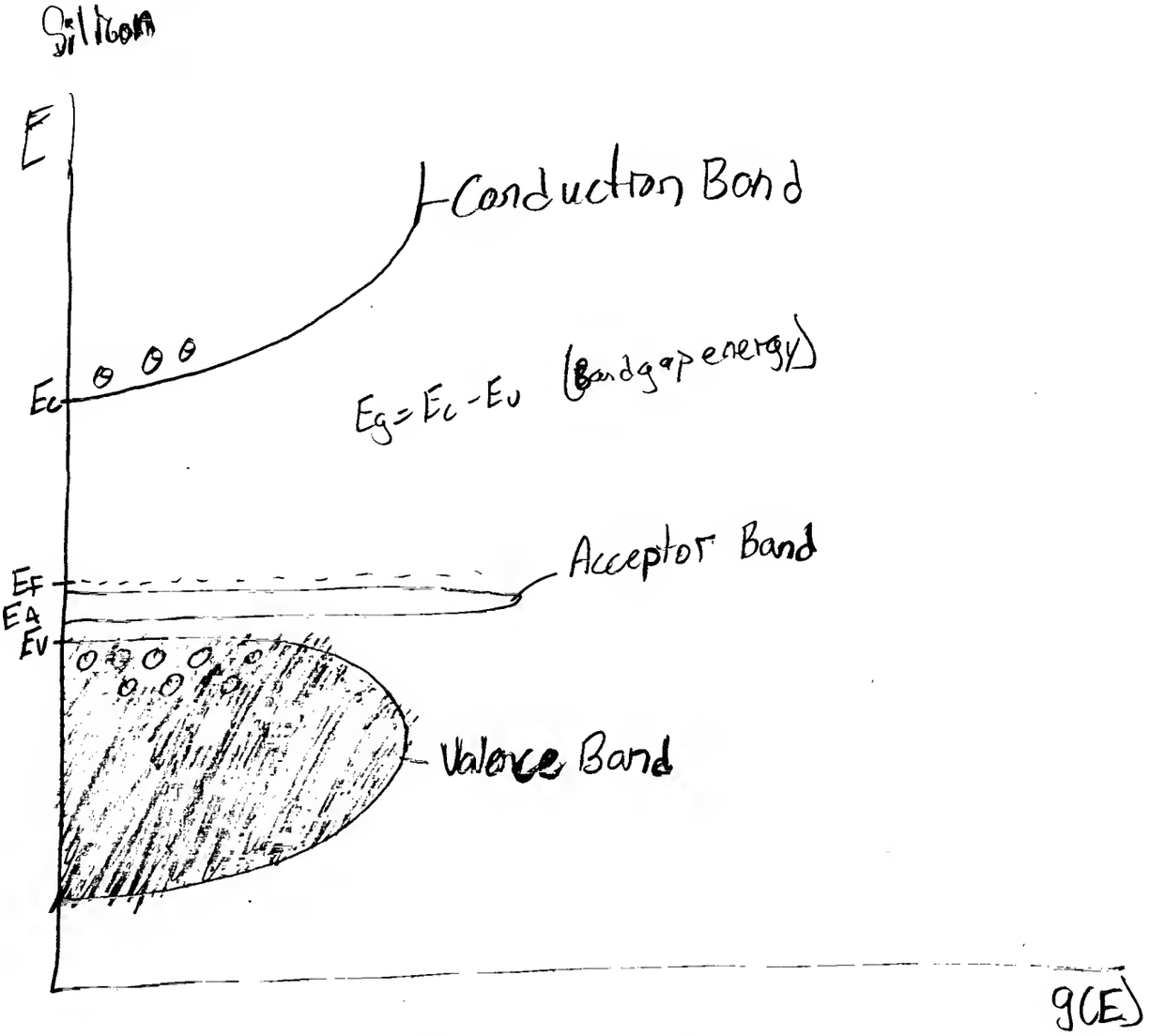

b) ✓

c) Classically we would think increasing I to ↑ Energy of wave as $I = \frac{1}{2}\varepsilon_0 E^2$ (Classical) but we find that ↑ intensity only increases the # of photons and that to increase E of photons we must ↑ ν since $E = h\nu$ ∴ $E \propto \nu$. (h constant)

✓

X. Semiconductor Band Structure

Draw a qualitative density-of-states diagram for *p*-type silicon. Label all relevant energy levels with appropriate symbols, and name the various regions of the density-of-states. Indicate the approximate position of the Fermi energy.




Few e⁻'s in CB from Thermal Energy.

Lots of holes in VB b/c Acceptors take e⁻s from VB.

3. Conduction in Semiconductors

a) Explain qualitatively the processes that limit the drift velocity of an electron traveling through a semiconductor.

b) Draw a qualitative graph of the density of electrons in the conduction band vs. temperature for n-type silicon. Provide an explanation why each region of the curve looks the way it does. The graph should be $\ln n$ vs. $1/T$.

c) Explain why a completely full band does not conduct electricity.

d) Under what circumstances will there be a diffusion current in a semiconductor?

4. Coulomb Potential

~~a)~~ What are the allowed values for each of the quantum numbers $n$, $l$, $m_l$, $m_s$?

~~b)~~ How many electrons can occupy each of following subshells: 3s, 2p, and 4d?

~~c)~~ What would happen to an atom if the Pauli Exclusion Principle did not hold?

a) $n = \{1, 2, 3, \ldots\}$ ✓

$l = \{0, 1, 2, \ldots n-1\}$ ✓

$m_l = \{0, \pm 1, \pm 2, \ldots \pm l-1\}^{\pm l}$ X

9 $m_s = \pm 1/2$ ✓

b) 3s = 2

2p = 6 ✓

4d = 10

c) If the Pauli exclusion Principle didn't hold all the e's would want to have the lowest Energy possible and would crowd around the nucleus. There would be no limit on how many e's could have the same $\psi$ and they would all bunch up near the nucleus. ✓

5. Lasers

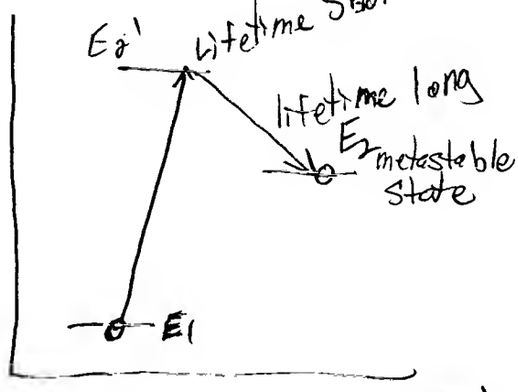
a) Explain the difference between spontaneous and stimulated emission.

b) What condition is necessary for optical amplification and how is it achieved? Explain using a typical energy level diagram.

c) Why is the light from a laser nearly monochromatic? Provide one explanation for why the laser's output has a small spread in wavelength.

a) In spontaneous Emission e⁻'s fall down in energy levels by themselves and emit a photon. In stimulated emission a photon passes by the e⁻ and it causes it to fall down an energy level and emit a photon that is in phase with the other photon.

b)




- photons are absorbed by e⁻'s and they raise up to $E_2'$ level.
- once there they fall back down to $E_2$ level or to $E_1$. If they fall to $E_2$ they last at this level a long time. After a while a lot of these atoms have e⁻'s that are at $E_2$ rather than $E_1$. This is called a population inversion and the process to reach it is called optical pumping.

* atoms not e⁻'s

* A population inversion is needed for optical amplification and is when more atoms are at a higher energy.

c) Light from a laser is nearly monochromatic because all the photons that are emitted carry the same energy and are the same λ. The reason it isn't totally monochromatic is b/c of diffraction when it passes through the end. ?x

this is what monochromatic means. why?

- The reason opp has small spread in wavelength is the doppler effect in that when e⁻ is moving away from you photon emitted has a lower λ red shift. e⁻ moving toward you photon emitted has a higher λ blue shift. These other wavelengths create the spread in the output.